General Application Name: Public Works/Service Authority

Product / Service / Function Name: Landfill Management

P/S/F Description:

The use of GIS for landfill management can be considered from two different perspectives: locating a site for a new landfill and maintaining existing landfills. The process of locating of a new landfill must follow regulatory criteria for fatal flaws, which for a large part is dependant upon soils. Land use and geology are also important key considerations from a natural resources point of view. Economic considerations may include analysis for hauling and site characterization, both of which may be derived to a large extent using GIS.

Monitoring of existing facilities involves the incorporation of fill data obtained through global positioning system technology (GPS). Site monitoring positions and environmental collection points are incorporated into a detailed survey base map. This data may then be utilized to visualize trends in the sampling data and results, derive best management practices (BMP) based upon site characterization, and be utilized for maintaining regulatory compliance and reporting. BMPs are activities or structural improvements that help reduce the quantity and improve the quality of storm water runoff.

Product / Service / Function

1. Spatial Data - Minimum Requirements – Optional Requirements

   Minimum Data Requirements

General Description	GIS Data Layer
Landfill	Boundary
	Monitoring Wells
Land Base / Planimetric Data	Jurisdictional Boundaries
Natural Features	Ecologically Critical Areas
	Flood Plains
	Geology
	Ground Water
	Open Water
	Soils
	Wetlands
Socio-Political	Demographic/Census Data
	Historical
	Hospitals
	Natural Parks
	Schools
	Land Use
	Zoning
Transportation	Street Centerlines
Utilities	Potable Water Wells
	Reservoirs

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Optional Data Requirements

General Description	GIS Data Layer
Land Base / Planimetric Data	Orthophotography
Natural Features	Terrace Areas
	Vegetation
Socio-Political Data	Fire Stations
Transportation	Airports
	Railroads
Utilities	Electric
	Gas
	Storm Water
	Wastewater System
	Water System

2. Attribute Data – Minimum Requirements – Optional Requirements

Minimum Attribute Requirements

GIS Data Layer	Attributes
Landfill	Site ID
	Property Address
	Acreage
	Waste Type
	Status
Buildings	Feature ID
	Dimensions
Streets	Address Ranges
	Street Name

Optional Attribute Requirements

GIS Data Layer	Attributes
Landfill	Year Constructed
	Closing Data (if applicable)
	Base Elevation
	Top Elevation
	Environmental Test Results
	Permit Status
	Ground Water Monitoring (Y/N)
	Dump Type

3. Data Acquisition Options (integrated with VBMP digital orthos)

   Locating a new landfill and managing an existing landfill require similar data. The only exceptions are monitoring wells and the exact landfill boundary. These two data layers are relevant only after the landfill becomes operational. The majority of the environmental and socio-political information (e.g. topography, wetlands) is available from federal data sources. These include USGS <www.usgs.gov>, the US Fish and Wildlife Services <wetlands.fws.gov>, the US Census Bureau <www.census.gov>, the Federal Emergency Management Agency <www.fema.gov>. Site-specific information, such as monitoring wells, must be collected via GPS or other surveying methods. Once in the GIS, all of the data associated with this feature (sample results, etc) will be available for visualization in the GIS. Supporting data, such as utilities, building footprints, land use, streets, etc. are typically maintained at the county or city level.

   Regardless of the source of the data, each data layer used to build the landfill site selection or monitoring should be consistent with, or be modified to match, the projection of the Virginia Base Mapping Project (VBMP) orthophotography. This is vital for data consistency and it facilitates data sharing across jurisdictional boundaries. The digital orthophotography provides an excellent base on which to display the landfill location and the surrounding area.

4. Data Conflation Options (integrated with VBMP digital orthos)

   Data conflation is a process by which two digital data layers, usually of the same area at different points in time, or two different data layers of the same area, are geographically "corrected" through geometrical and rotational transformations so that the different layers can be overlaid on one another. Also called "rubber-sheeting," this process allows a technician to adjust the coordinates of all features on a data layer to provide a more accurate match between known locations and a few data points within the base data set. A good base layer to use for data conflation is the VBMP orthophotos since many features can be seen or interpreted. The need and processes for conflation varies between sets of data, users, and feature types. Any dataset that is updated independently by different departments can be consolidated through conflation. Within most local governments, individual departments are responsible for maintaining specific datasets within their expertise; therefore, conflation is not often necessary. Often, reprojecting the data into a different coordinate system will take care of the misalignment of different data sets. Most industry-standard GIS software has the ability to perform data conflation.

   In the case of landfills, the VBMP orthophotography will greatly assist with monitoring extent, elevation/height, and other visibly identifiable features of the landfill. This, combined with historical data, will allow the user to analyze growth, impact, and extent of impact of the landfill. Additionally, the VBMP orthophotography may be used as a baseline record of the status of the landfill, if no other GIS based study has been completed.

5. GUI / programming options

   There are many options for developers of GIS-based landfill-related applications. Two avenues within this development track are:

   - Off-the-shelf GIS desktop application that can be customized to the user's needs
   - Purchase existing commercial software
   - Hiring a consultant to develop a custom system from scratch.

Using a standard GIS software package often requires a significant amount of training and customization. Whereas the initial cost may be lower, the time invested in learning these solutions may generally increase the overall expense of implementation. However, standard GIS software packages deliver more robust data integration, analysis, and cartographic capabilities than do other specialized commercial applications. They have a greater user support infrastructure that allows users to overcome problems quickly. Options for using an existing, industry-standard GIS software application that can be customized for property inventory include those listed in the following table:

Standard GIS Software Vendors:

Vendor	Software	Web Address
ESRI	ArcView 3.x	www.esri.com
ESRI	ArcGIS 8.x	www.esri.com
MapInfo	Professional 7.0	www.mapinfo.com
Intergraph	GeoMedia 5.0	www.intergraph.com/gis
Manifold	Manifold 5.0	www.manifold.net

There are limited tools for landfill evaluation processes – either from the site selection or the monitoring perspective. Site selection is typically carried out through iterations that involve complex decision-making matrixes. However, there are some commercial products available that can assist in analysis functions. ESRI's ModelBuilder is a tool in the ArcView Spatial Analyst extension that helps create spatial models for geographic areas. A model is a set of spatial processes that converts input data into an output map using a specific function or set of functions. EPA's BASINS is a multipurpose environmental analysis system for use by regional, state, and local agencies in performing watershed and water quality based studies. This new software makes it possible to quickly assess large amounts of point source and non-point source data in a format that is easy to use and understand. BASINS is useful for both site selection and for monitoring and remediation. A final example of commercial software for site specific monitoring or other environmental data management is Enviro Data. This software, by Geotech Computer Systems, is a program for managing and displaying site environmental data.

Commercial Software:

Vendor	Product	Web Address
Geotech	Enviro Data	www.geotech.com/envirodata.htm
EPA	BASINS	www.epa.gov/waterscience/basins/basinsv3.htm
ESRI	Spatial Analyst/Model Builder	www.esri.com

The final option for developing and implementing a GIS landfill related application is to contract a consultant. This option makes certain that a product will fulfill a jurisdiction's requirements. A consultant will be able to develop an application that works with the wide range of hardware and software that are currently in use within local governments within Virginia. Also, training and follow-up user support is often provided at a much more substantial level than with other options.

A GIS-based landfill management application should provide functionality in either one or both of two major tasks: landfill site selection or landfill monitoring. A site selection tool should allow the input of several factors, including property size, soils type, etc., which would then calculate

and display ideal available locations for a new landfill. A landfill monitoring tool would be able to map the results of samples taken at an existing landfill and as well as create various reports.

6. Internet Functionality and options

The Internet has proven itself as a viable solution for local governments to centralize the maintenance and management of services and data. As more local governments are implementing Web-based solutions, they are finding that the Internet requires them to change the nature of an application or its usefulness. Through the flexibility of an Internet solution, software can be easily updated, and users gain greater accessibility to the applications and information they need for their specific tasks through simple, user-friendly interfaces.

An application can be deployed on the Web to allow access to information for the community. Public participation is a critical component in the selection of a new landfill site. Through the use of on-line maps, querying tools, and the ability view model output based upon multiple criteria, the public can make informed decisions. GIS software vendors have products that can be customized in-house or by a consultant to provide Web GIS applications on the Internet, over an intranet or via wireless network. The table below shows GIS vendors and their Internet mapping solutions.

GIS Internet Solutions

Vendor	Internet Software	Web Address
ESRI	ArcIMS	http://www.esri.com/software/arcims
MapInfo	MapXtreme, MapX	http://www.mapinfo.com
Intergraph	GeoMedia WebMap	http://www.intergraph.com/gis/gmwm
AutoDesk	MapGuide	http://www.autodesk.com

7. Minimum Technical Requirements – Optimum technical requirements

Minimum Technical Requirements
At its most basic level, a GIS-based landfill management application can be used on a single, stand-alone workstation. This workstation would have a hard drive that stores all of the spatial data layers, as well as the GIS software package or application itself. A typical workstation running off-the-shelf software should have the following minimum specifications:

Processor:	Pentium 3; 450 MHz
RAM:	128MB SDRAM at 133MHz
Hard Disk:	20GB (min.)
Monitor 1:	19"
Floppy Drive:	3.5”
CD-ROM:	12x/8x/32x CD drive
Modem:	56K
OS:	Windows 2000/NT/XP
Office:	Windows 2000 Professional
Printer:	8x11 office-grade color printer

Optimum Technical Requirements:

A more complex application may require multiple components, including servers, desktop workstations, or handheld devices. The scale at which the system is implemented, thus the technical needs, is dependent on the number of daily GIS users as well as the number of data collectors. For either a desktop or a Web-based application, the system should rely on a fairly robust server computer and high-end workstations. Some examples specifications of the necessary equipment are listed below:

Server

Processor:	Min. 2x Processors, 1.7 GHz, 512K cache
RAM:	Min. 2x 512MB RIMMS
Hard Disk:	Min. 2x 80GB +RAID
Monitor 1:	19"
Floppy Drive:	3.5”
CD-ROM:	12x/8x/32x CD drive
Modem:	56K
Network Card:	10/100 mbps

Workstation

Processor:	Pentium 4, 1.5 GHz
RAM:	512MB SDRAM at 133MHz
Hard Disk:	20GB (min.)
Monitor 1:	19”
Monitor 2:	17”
Floppy Drive:	3.5”
CD-ROM:	12x/8x/32x CD-RW drive
Modem:	56K
Network Card:	10/100 mbps
OS:	Windows 2000/NT/XP
Office:	Windows 2000 Professional

Other Components

Printer:	8x11 office-grade color printer and 8x11 production b/w printer
Plotter:	HP DesignJet 1055CM
Tape Backup:	Tape Library Server
UPS:	APC 1400 (or other similar)
Scanner:	11x17
Handheld:	Compaq IPAQ
Network:	T1

8. Administrative/Management Requirements

At the beginning of the project, the assigned project manager from the particular municipality should consider completing some, if not all of the following tasks that relate to the administrative requirements of a landfill analysis application:

- Determine, with or without the assistance of a consultant hired to develop the system, the preliminary vision and goals of the project.
- Coordinate an initial meeting with the decision-makers (i.e. the Board of Supervisors, City Council, local/state environmental agencies, landfill manager, etc.) where the vision and goals of the project are expressed and the background of GIS technology is described, if needed.
- Coordinate with other municipal agencies for data sharing provisions.

- Determine a mechanism of communication to keep the decision-makers aware of the progress of the project.
- Develop a basic understanding of the available precedents in the region/state and research the available technologies that can be applied to the project.

Upon project completion, a basic GIS-based landfill management application will require very little administrative support. Administrative tasks may include loading or upgrading new versions of the software or patches, providing for constant data flow from the source database, and maintaining yearly support contracts on the hardware and software. However, once the system becomes distributed as an enterprise solution to many users throughout a department or deployed on the Internet, there are various other management requirements that need to be fulfilled on a weekly or monthly basis.

At the point where the system grows beyond single desktop users, a devoted administrator or system manager needs to be established. This is essential for the following reasons:

- The system will now be interfacing with other technology systems already in place. Therefore, someone needs to maintain contact with the technology personnel that maintain these systems.
- The manager needs to put into place training schedules to maintain user knowledge of the system.
- Funding will undoubtedly be required to either maintain the system long-term, or continue to expand the system, which requires funding research and applications for grants.

9. Cost – Cost/Benefit

Hardware	**Typical Unit Cost**
Minimum Workstation	$2,000
Optimum Workstation	$3,200
Laptop	$2,400
Web/FTP Server	$8,500
Database Server	$12,000
Data Warehouse Server	$18,000
Backup Server	$5,800
Printer (8x11 color)	$700
Printer (8x11 b/w production)	$2,000
Plotter	$12,000
Tape Library	$5,000
UPS (Universal Power Supply)	$700
Scanner	$1,500
Handheld	$300-$700

Software (all prices included license)	**Typical Unit Cost**
Standard GIS desktop software	$700-$10,000
Customized desktop vendor solution	$5,000-$15,000
Web-based vendor application	$15,000-$25,000
Customized web-based vendor solution	$20,000-$60,000

Miscellaneous	Typical Unit Cost
Training – focused vendor training (per person)	$700-$1,000
Training – general GIS	$700-$1,200
Licensing – desktop	$100-$500
Licensing – webapp (1st CPU)	$7,500-$12,000
Maintenance (per year)	$8,000-$15,000

10. Standards / Guidelines Summary
    - A GIS-based landfill application should be built so that non-technical personnel can be trained to use the system.
    - Identify the proper regulations that must be followed for locating a new landfill site.
    - Create a model (identify the variables) for the landfill site selection process and have it approved by all parties involved.
    - A landfill monitoring application should meet the requirements of any state/local/federal environmental requirements.
    - Develop a detailed Quality Assurance/Quality Control (QA/QC) procedure for reviewing the accuracy of the GIS data and its attributes.
    - Maintain data in the VBMP standard coordinate system (Virginia State Plane, NAD 83, Survey Feet).
    - Create metadata (standard information about GIS data) for each data layer. Metadata tracks the date, origin, coordinate system, and other such information for data layers.

11. Startup Procedures/Steps

    There should be a minimum of eight steps involved with developing a GIS-based landfill management application after funding is in place to support the project. The steps can be performed in-house or by a consulting team.

    The first task is to complete a detailed Needs Assessment. This process gathers information regarding existing operational procedures, hardware and software, GIS data, and personnel needs. It should include interviews of key individuals throughout the local government agency and other related government departments to obtain a comprehensive view of the agency's operations, and where GIS might improve them. Basic GIS concepts should be discussed and illustrated to those interviewees that have little prior understanding of GIS. A comprehensive Needs Assessment should then be compiled from the results of the interviews. This document explains the various requirements for a GIS-based landfill management application in the following areas: personnel needs, spatial data development needs, applicable spatial analysis techniques, basic system requirements, including preliminary, general hardware and software recommendations, and training needs.

    The second task is to develop a functional requirements document for the proposed system. This document should describe, as completely as possible, all of the technology and functionality that is to be included in the system. This document is used by the local government agency, or its consultant, as the blueprint for the GIS application or system.

    - Hardware specifications
    - Software purchases
    - Detailed descriptions of work-flow, and examples of the graphic user interfaces
    - Describe each tool that is part of that graphic user interface, and its functionality

- Describe how data would flow between the different databases and data warehouses, if applicable
- Describe the redundant security measures that will be put in place to make certain of data integrity and confidentiality, when applicable
- Analytical techniques that the application/system provides the user for analysis
- Describe each of the potential products (reports, maps, charts, summary tables) that the user will be able to generate within the system

The third task should be to compile or develop spatial data that can be used by the evolving application. Data can be gathered from a number of online sources, as well as county/city departments. The data layers gathered and maintained should match at least the minimum list provided in Section 1 of this document and can be acquired through the methods described in Section 3 of this document.

On completion and acceptance of the functional requirements document and the development of the spatial and attribute data, the system development and test phase can begin. During this time, the application will be customized as it was outlined in the functional requirements phase. The local government agency should require periodic reviews of the application at particular milestones, such as 50% and 75% completion. This will make certain that problems with the application will be recognized early in the development process, and that the local government agency remains a part of the development process throughout the project timeline.

When the application is nearing 100% completion, it should be installed and tested in the environment in which it will ultimately be used. This allows the users to test the system alongside the application developers, and determine any system integration problems that might arise. It also gives the developers the opportunity to test the application's functionality in a real-world situation. This testing process should be as comprehensive as possible. Each process detailed within the functional requirements should be tested and evaluated at this point.

User training commences once the application reaches 100% completion and is fully documented. Different levels of tutorials and system documentation should be developed depending on the hierarchy of users. Time should be spent at this stage of the project with each potential user of the system to make certain that the proper education occurs. Training should be done through lessons that use real-life examples of system application. This strategy greatly enhances users' ability to apply the functionality to their jobs.

The next phase of the project should include a document that describes a future plan for wider system development. This document accomplishes two goals. The future plan gives the local government agency ideas on how the system might grow to assist other facets of its business practices. Secondly, it provides the agency with a ready-made grant proposal for applying for potential funding sources.

The final phase of a successful implementation of a GIS-based landfill management application is ongoing technical support. The local government agency should always include this contingency within its cost estimates of a project for a minimum of three months after a system has been put into place. No matter how effective an application appears, problems and system changes inevitably impact the functionality of an application.

12. Estimated time line and/or implementation (stand alone) schedule

Phase	Approximate Duration
RFP/Contract process (construction, posting, proposal acceptance, review, award of contract)	4 months - 1 year
Needs Assessment	2 months
Functional Requirements	1-2 months
Data Development	6-12 months
System Development and Testing	2-4 months
Installation and Testing	1 month
User Training	½ month
Plan for Future Development	½ month
Ongoing Support	3 months

13. Best Practice Examples in Virginia

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